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THE U.S. NAVY'S HYDRA PROJECT, AND OTHER FLOATING-LAUNCH PROGRAMS

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ABSTRACT:

This paper describes a number of programs employing floating launch rockets that have been initiated by Germany, the United States and the USSR. In Germany, near the end of WWII, plans were drawn up to encapsulate V-2 missiles, tow them behind a submarine, and launch them into New York City. This was the so-called "New York Rocket" (never used). The earliest floating rocket launch efforts in the US were tests carried out under Project HYDRA in the early 1960s at the Naval Missile Center. They culminated in several successful operational probe rocket programs, yielding scientific data on upper atmosphere and ionosphere environments. The earliest Russian floating launch rocket to appear was a relatively short range towed missile named "Golem", in 1961. Subsequently, a number of Russian liquid SLBMs employing the floating launch have appeared, including the SS-N-6 and SS-N-8 missiles, and were produced in large quantities. In 1984, the US commercial company Starstruck designed, built and launched the Dolphin, prototype for a commercial floating launch satellite booster. The Naval Research Laboratory initiated a program in 1988 named SEALAR aimed at developing a reusable pressure-fed liquid satellite booster. In 1993, US and Russian entrepreneurs formed a joint venture to convert Russian SLBMs into satellite launch vehicles. More recently, Sea Launch LP (whose major partners are Boeing, Kvaerner and Yuzhnoye) are planning to launch ZENIT rockets commercially from a converted floating oil rig. Although not a true floating launch , many of its advantages are present- such as low cost, mobility, range safety, equatorial launch, etc. Had the floating launch been fully developed in the early 1960's, present day satellite launch costs would almost certainly be much lower due to the avoidance of costly land-based, vehicle-specific launch infrastructure.

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INTRODUCTION:

"Who Needs a Launch Pad When We have the Sea?" This headline appeared in the March 1994 issue of *Popular Mechanics Magazine*. The article briefly mentioned the development of the floating launch by the US Navy under Project HYDRA in the early 1960's. Then it went on to describe a joint venture by Russian and American entrepreneurs to convert Russian SLBMs, scheduled for deactivation, into satellite launch vehicles. These rockets, readied for launch on board a large Russian amphibious assault ship- the Ivan Rogov- would be merely dropped in the ocean. Quickly erecting themselves to the vertical, with only a portion of the nose of the rocket above water, they would be ready for launch by telecommand from the mother ship. The 100-ton launch vehicle itself, named by the Russians the "Priboy" (English translation: "Surf"), was capable of placing 2.4 metric tons into low Earth orbit, at a cost of less than $10M. The next time you go to the beach, take a trip aboard a cruise ship, or fly across the Atlantic, take a closer look at the ocean and use your imagination. The ocean represents, among other things, a no-cost, self-healing launch pad for either military or commercial rockets. Any suitably waterproofed rocket, with the proper specific gravity (0.8-0.95), floating by itself upright in the water, is ready for countdown and launch using this no-cost pad! Prior to launch it is actually being supported in the most efficient structural manner possible, (with no stress concentrations such as occur using land launch platforms). Underwater ignition of the rocket is not a problem. A simple waterproof seal across the nozzle throat is all that is needed to protect the rocket prior to rocket ignition. At ignition, the seal is expelled by the pressure of combustion. Thus, a body of water deep enough to float a rocket really is "Mother Nature's Launch Pad"!

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CHRONOLOGY

In this document, the various national efforts are covered from the perspective of the author. Thus, they do not fall in exact chronological order, but rather are discussed in the sequence they became known to the author himself, in his studies on floating launch.

THE US NAVY'S PROJECT HYDRA

In the late 1950's the major superpowers- the US and the USSR- found themselves in a race to place the first man-made satellite into orbit. The U.S. Navy's VANGUARD satellite was, as we know, a dismal failure at the launch pad. The USSR was more successful with the Sputnik-1 in October 1958. This event was to change the world forever. The 'space race' also had its counterpart in the weapons race, with the two superpowers vying in all fields of weaponry, including strategic rocket forces (both land- and submarine-based)

In February 1958, the author was assigned to the Naval Missile Center at Point Mugu, California. The technical and engineering challenges of the time were both interesting and appealing. One pleasurable series of events were the occasional Saturday evening "Beer and Science" cook-outs held at the home of one of the senior NMC engineers, Mr. E. Quimby Smith. It was there that the author, then a young naval lieutenant commander, was motivated to participate in the exciting new challenge of space. Fortunately, his superiors lent a friendly ear, and they soon established a new "Astronautics Branch" at the Missile Center, commanded by CDR "Doc" Freeman, USN. Under this branch were two divisions. The first was the "Astronautics Research Division" commanded by the author; the second was the "Astronautics Programs Division", commanded by LCDR H. Henning.

One of the first tasks assigned to the Astro Research Division was to respond to a Navy Operational Requirement for a booster capable of launching a manned maneuverable space interceptor from a marine environment. Several companies had baseline designs for the space vehicles, but they had only considered using conventional land launches from the recently established ranges at Vandenberg and Cape Canaveral. Considering the large mass to be orbited, it was evident that something much larger than the SATURN I being developed for NASA was required. Many space scientists referred to this next generation, larger launch vehicle as the "NOVA" class- about four times the size of a SATURN 1-B. But, how would it be possible to launch this from the ocean??

Approaching the basic requirement, other U.S. naval engineers had considered the use of a standard floating dry-dock, used for docking naval ships, as a launching pad. To us in the Astro Research Division, even this approach appeared infeasible, due to the instability in righting moment that would be induced by such a large mass with such a high center of gravity with the rocket in the erected position. Finally, the author and his assistant, LT Charles E. Stalzer, concluded that the only way to handle a rocket as big as a ship in the ocean was to (a) treat it like a ship when it was horizontal, and (b) treat it as a very large spar buoy when it was vertical.[1,2] It would probably have to be towed horizontally in the ocean until reaching the launch site, or carried horizontally on a barge or in a floating dry dock. When free in the water, it would then be erected to the vertical through means of ballast near the nozzle end. (Later in the program, we did find it feasible to tow very large rockets for short distances in the vertical floating attitude.)

The next problem facing the author was funding for the floating launch research and development. There was nothing in the Navy's five-year budget for this type of work. The Commander of the Naval Missile center had a very small amount of discretionary funds for R&D at his disposal, but even this was already committed and out of our reach. Although we were denied funding, we did receive many encouraging words and offers of manpower and ship support! Accordingly, we decided to beg, borrow, or steal the remaining wherewithal to conduct our analyses and tests, vowing to extract accurate engineering data to facilitate follow-on efforts. Fortunately, we had an almost unlimited- and free- supply of various types of surplus rocket motors at the Naval Missile Center. At this point we decided to proceed on a parallel path- employing paper studies to predict what the performance of water-launched rockets should be, as well as backing these up with live rocket experiments to verify the analyses. It would be a low-cost, bootstrap effort. In fact, we joked among ourselves about "launching no-cost rockets from no-cost launch pads"!

As we were working in what appeared to us to be an entirely new field of technology, we coordinated closely with the NMC Patent Attorney to obtain US government patents on the basic floating launch concepts and techniques. Over the next few years, about a dozen US patents were granted to the HYDRA team, all of them being assigned to the US Navy. The basic floating launch US patent assigned to the Navy was filed by NMC on May 6, 1960, and issued on February 12, 1963.[3] (The reason that the US government obtains patents is basically to avoid the payment of royalties, since the same inventions could well be patented later by speculators outside the government.) Other patents followed.[4]

Fortunately, the Naval Missile Center had all the infrastructure we needed- range facilities (radars, telemetry, ships, boats and aircraft), plus skilled personnel, (both active naval personnel and civil service engineers and technicians). The only thing remaining was to convince all of our coworkers, as well as our superiors, that what we were doing was very important to the future of the Navy, and the country. The first step in this process, we reasoned, was to show these people and others that the concept of the vertical floating rocket launch really worked. If the nay-sayers saw an actual rocket rising from the water, we reasoned, they would be forever silenced!

Our first operating vehicle was named HYDRA I. It was a five-foot long wooden body (the "fence post") turned on a lathe to approximate the shape of a POLARIS missile (then under development) complete with rounded nose. By drilling a hole from the base end, we inserted a 2.25" diameter AEROSCAR rocket. A set of four tail fins was added to give it post-launch aerodynamic stability. An electrical firing lead about 75 m long attached to the nose doubled as a tether for the first launch; this wire was connected to a standard explosives detonator. In our zeal to hold the costs to zero, the author was somewhat dismayed to see a financial printout charging the HYDRA Project a total of $5.75; further investigation revealed that this amount covered the cost of a gallon of white paint used cosmetically and as protection on the HYDRA I rocket body and fins.

On the day of the first launch of HYDRA I, the small rocket vehicle was placed in an inflatable life raft, and two Navy Seals paddled out into Mugu Lagoon (an inland tidal basin at the Missile Center. After reaching the limit of the firing lead, the Seals dumped HYDRA I into the water and returned to shore. The Test Conductor quickly conducted a very businesslike countdown, as every respectable rocket launch required. At the end of the countdown, a Navy ordnanceman pushed down on the plunger to ignite the AEROSCAR rocket motor. HYDRA I smoothly and rapidly accelerated vertically upward until it reached a point where the still-attached tether started tugging at the nose and slowed its trajectory. Losing its upwards momentum, it fell back into the lagoon where it happily bobbed up and down a few times before it was recovered. We considered this test a complete success, and it was soon followed by many more. On the second test we released the tether on firing so that the rocket would no longer be restricted on leaving the water, and could seek its natural trajectory. After a half dozen or so test firings, the Commander of the Naval Missile Center and the Public Affairs Officer decided to "go public". They arranged a public test firing on April 22, 1960, aimed at giving the Navy some good (and <u>very</u> inexpensive) press coverage. TIME magazine printed a very favorable article, with a photograph of a HYDRA I launch, pointing out that the technique could easily be used for missiles as well as for satellite boosters.[5] Over a dozen successive launches were made with this vehicle until it was lost, having apparently buried itself in the mud bottom during a lagoon launch in shallow water.

While the HYDRA I was an excellent demonstration vehicle, we decided to build a larger, more powerful research rocket named HYDRA IA. This was highly instrumented with accelerometers and pressure pickups, with all data being returned through a telemetry link. HYDRA IA gave us a wealth of excellent technical data on floating launch phenomena.

In an effort to better simulate the length of an actual satellite booster, including nozzle firing at greater depth, the next launch demonstrator selected was a 105-foot long telephone pole, borrowed from the Public Works Department of the Center. The rocket motor was attached to the pole by means of a cylindrical steel adapter with small corkscrew fins welded on sides of the cylinder. These were deemed necessary to ensure a slow rotation of the pole to counter any thrust misalignments. The first launch used three solid SPARROW motors, with a total of about 22,000 pounds thrust, and lifted the telephone pole to 375 feet altitude. The second pole launch used a single surplus Air Force GENIE motor developing 36,000 pounds thrust, and reached an altitude of about 450 feet. In both cases the instrumented pole rose rather majestically from the Pacific Ocean a mile off the beach at Point Mugu, and then fell back into the water still very close to the vertical. After water re-entry on the second launch the pole was shattered in two pieces due to impact with the bottom. We felt obliged to apologize to the Public Works Officer for breaking his pole, but, had to admit that we were unable to pay him for it!

While the HYDRA I, HYDRA IA, POLE I, and POLE II tests were going on, we were designing a new and larger test vehicle with more extensive instrumentation and a ballasting capability that allowed easy transition between horizontal and vertical floating attitudes. This vehicle (HYDRA II) was constructed of boiler-plate steel by the Long Beach Naval Shipyard (at a cost of $9,000), and was powered by a GENIE motor. The total ballasted vehicle mass approximated ten tons, giving a T/W ratio of 1.8. On September 26, 1960, HYDRA II was dropped horizontally into the surf from a surplus boat retriever ("Jeheemy"). It was then towed out to a point a few hundred yards off the beach where it was ballasted to the vertical. A ten-second countdown ended with a firing signal sent by hard line from a nearby boat. The rocket rose vertically from the water with scarcely a ripple until the nozzle broke the surface, accompanied by an eruption of water, steam and rocket gases. It then continued rising to about 150 feet before falling back vertically. It was totally undamaged and readied for the next series of launches. All of the later HYDRA II launches were conducted using a converted wheeled R3Y seaplane beaching cradle with vertically adjustable flotation. This cradle made it easy to either dock or recapture HYDRA II (or any of our other test vehicles) in a horizontal floating attitude in any depth of water. Several launch operations were conducted off the beach at Point Mugu, and then more launch exercises were conducted from aboard the USS ALAMO, a Landing Ship (Dock), in the vicinity of Santa Cruz island, off the coast of California. The seaplane beaching gear was easily operated from the well deck of the ship, and absolutely no ship modifications were necessary. Color and still photography of all of these operations was considered very important, and the NMC Photo Unit made a number of excellent documentary films of all of these and subsequent launches. By the end of 1960, PROJECT HYDRA had completed several dozen launches, still with close to zero funding!

In view of the fact that all of the rockets previously used in PROJECT HYDRA were of the solid propellant variety, we decided to try a liquid propelled vehicle. An experimental liquid rocket had been developed for SPARROW missile propulsion, and was pressed into use for floating launch. This rocket motor was attached to a forty-foot length of steel pipe, and unceremoniously dubbed "the sewer pipe". That was the only name ever given to it, and it stuck. This test vehicle also was successfully launched without difficulty.

One day, Mr. John Masterson, the Head of the Meteorological Unit at NMC, contacted the author. He stated that he had an ARCAS meteorological sounding probe rocket with a bent fin, and that he didn't want to risk launching it from the land pad at Point Mugu. (A few weeks earlier an errant ARCAS had landed only yards away from an expensive home in Malibu Beach.) We immediately accepted his offer, and followed it up with a call to rocket's manufacturer, Atlantic Research Inc., in Virginia. We told the chief engineer that we were planning to use this rocket for an open-ocean HYDRA test. If it proved to be successful, we would call it the "HYDRA-ARCAS"; however, if the launch turned out to be unsuccessful, we would just pass it off as just another ARCAS launch. The manufacturer quickly agreed to repair or replace the bent fin at no charge to our project, and also to pay transportation charges for the rocket to and from their factory in Virginia.

In parallel with all of the HYDRA test firings, a considerable number of analytical studies were initiated. Hydrodynamic analyses and wave tank tests on the motion of floating rockets in a wave front were conducted by Mr. Jan Leendertse at the Navy's Civil Engineering Laboratory at Port Hueneme, California.[6] Additional theoretical and systems type studies on underwater rocket firings were undertaken by the U.S. rocket industry (which had by then become fairly interested in Project HYDRA). These were called "no-cost study contracts"; they actually cost the Navy a nominal $1.00, in exchange for which the Navy provided program data. These rocket industry analyses were supplemented by work carried out at universities, as thesis or workshop projects (also at no cost to the Navy). In all, over 100 reports, analyses, studies, or student theses were generated under Project HYDRA on floating launch technology, during the 1960's.

Early in 1961, the author learned that NASA had experienced an accident with one of their ALGOL solid rockets (first stage of the SCOUT satellite booster). The motor had rolled off a moving flat-bed truck and onto a sandy road divider. NASA was unwilling to chance using the motor on an actual SCOUT mission, and after considerable pleading the author obtained the motor for use in a Navy floating launch test. We reasoned that if the damaged motor blew up at ignition there would be little or no monetary loss to the project from either the vehicle or the launch pad (water). A design for a large single stage HYDRA probe with fib stabilization was prepared; it was named HYDRA IV. Its apogee altitude was calculated to be at least 260 km. Being similar in size to HYDRA II, many design and operational features (including use of the seaplane beaching gear) were incorporated into HYDRA IV. HYDRA II was then converted into a "handling dummy" for HYDRA IV by adding the same fins and ballast tank. Additional at sea tests were conducted using USS POINT DEFIANCE, a sister ship of USS ALAMO. These tests were designed to sharpen the handling skills of the launch crew, particularly the boatswains mates, so that they could later handle HYDRA IV (the "live" rocket) in the ocean without damage.

In order to get far enough away from the coast to prevent any impact on land, we calculated that the unguided, fin-stabilized HYDRA IV would have to be launched at least 500 miles from the nearest land. Since we were trying to demonstrate the possibility of launching large, multi-stage satellite boosters from the ocean, we decided to make it a really interesting demonstration by going all the way to the Equator. (This approach would also demonstrate an efficient way to launch directly into a geo-stationary equatorial plane orbit!) While at the Equator, along with the HYDRA IV, we planned to also launch the now refurbished HYDRA-ARCAS meteorological probe. This vehicle was intended to be the first of a series of operational scientific probe rockets, using the floating launch.[7]

In June of 1961, USS Point Defiance departed Port Hueneme, with the Project HYDRA launch team, the HYDRA IV and the HYDRA-ARCAS, plus support equipment. Arriving at the Equator expecting to find the equatorial doldrums (flat sea, little wind, humid conditions) we were surprised. There was a moderate wind, state 3+ seas, and occasional showers. In spite of these less than perfect launch conditions, we attached the aft ballast tank to the rocket in record time, in the well deck, with the ship rolling about five degrees. This bettered even our best on-land performance at Point Mugu. The launch operation proceeded normally for the rocket extraction from the ship. Some difficulty was experienced, however, with separation of the rocket from the seaplane beaching gear. The flotation attachment hooks had rotated off axis, partially releasing several of the flotation quadrants. The mechanical hook design in use had been adopted by project engineers because the project did not have sufficient funds to purchase explosive bolts (the preferred release method). After about two hours, the flotation quadrants began breaking off, and after consultation with the ship's captain, the author had no choice but to abort the operation. The Seal team disarmed the firing circuits while the HYDRA IV was still horizontal in the water. Shortly thereafter, the last two remaining upper flotation quadrants separated and the rocket then up-ended; it now floated vertically downward buoyed by the nearly empty aft ballast tank. In view of the worsening sea state, the attitude of the rocket and the approach of nightfall, the author and the captain of the ship decided to scuttle the rocket rather than attempt a salvage operation. The author personally wielded a fire ax to punch holes in the aft ballast tank; HYDRA IV then sank in 2,000 fathoms of water at 0° latitude, 120° West longitude- over 2000 nautical miles south of Los Angeles.

On the day following the loss of HYDRA IV, the HYDRA-ARCAS was prepared for launch. In contrast to the 14-ton HYDRA IV, this launch did not require use of the seaplane gear or any boats. The stern-gate of the POINT DEFIANCE was simply lowered, with about ten feet of clearance to the water. From this "back porch", the author and a Chief Petty Officer of the HYDRA team lowered the HYDRA-ARCAS into the water. The ship moved off a half mile, and the rocket was fired without difficulty by radio command to its full apogee altitude. The motor had been ignited with the nozzle at approximately 2 meters underwater. The nozzle had been waterproofed using an inflatable rubber seal which blew out at rocket ignition. This successful launch partially offset the gloom following the loss of HYDRA IV, but everyone aboard would have preferred the failure to have occurred to the smaller HYDRA-ARCAS instead of to the more important HYDRA IV.

During 1961, Project HYDRA had begun developing a larger probe rocket for operational HYDRA launches. This was the single-stage Atlantic Research IRIS, a much larger rocket than ARCAS. The HYDRA-IRIS actually had considerably more performance than even the standard IRIS single-stage probe, since it was boosted out of the water by three solid SPARROW motors, ignited simultaneously with the IRIS sustainer. The total length of HYDRA-IRIS was 8 meters. Payloads between 45 and 112 kg could be launched to apogees up to 204 km. This scientific probe rocket was routinely launched for scientific research from numerous locations in the Pacific, South Atlantic and Antarctic Oceans in the mid-1960s. Payload sponsors were the Naval Missile Center, Lawrence Livermore Laboratory, and the Naval Research Laboratory. HYDRA-IRIS proved to be instrumental in gathering technical data on upper atmosphere composition including radioactive particle fallout.[8]

In the late 1960s a replacement for the HYDRA-IRIS was developed, having even greater performance and an improved flotation system. This was the HYDRA-SANDHAWK. A number of operational launches were carried out using this HYDRA-type probe rocket. Finally, in the 1970's, much of the space research that had been done mainly by probe rockets was being accomplished by satellite borne sensors. Also, the US Air Force had been given a virtual monopoly on the development of space systems, by virtue of DoD Directive 5160.32 signed by Defense Secretary MacNamara. The Navy's space program had been dealt a blow from which it would never fully recover.

GERMAN FLOATING-LAUNCH STUDIES: THE "NEW YORK ROCKET"

In the summer of 1961, the author received a request from Dr. Wernher von Braun to visit Redstone Arsenal in Huntsville to brief him on Project HYDRA. Meetings were also arranged with Kurt Debus and Georg von Tiesenhausen. Dr. von Braun appeared especially impressed with the colored motion picture films showing the long HYDRA II and HYDRA IV vehicles being dragged out of the cavernous well-deck of the LSD in their seaplane flotation cradle, with almost immediate separation and ballasting to the vertical. He also was impressed with the stillness of the surrounding water during launch, before the nozzle broached the surface. He remarked that this Navy launch technique appeared well suited for military operations, but was not feasible for the large liquid propellant satellite boosters planned for NASA missions. Before leaving Huntsville, the Redstone team of rocket scientists presented the author with the German shipyard blueprints for the V-2 rocket capsule. These were subsequently turned over to NMC by the author. It was intended that three of these encapsulated missiles would be towed behind a German submarine. This was the "New York Rocket", referred to by Walter Dornberger in his book "V-2"! The German operational plan was to have the submarine surface at night twenty miles off New York City, where it would release the missile capsules, ballast them to the vertical, open the lids of the capsules and then launch the V-2s into Manhattan Island! ("Wall Street" was even referred to as one of their primary targets!) There were steel ladder rungs welded both inside and outside the capsule, to allow technicians to access the V-2 missile before launch. Also to allow access, there were watertight caps at the nose end of the capsules, that could be opened after ballasting them to the vertical. Apparently, none of these capsules were ever constructed; thus, no tests on sea-launching the V-2 ever had taken place by the end of WWII. Had the war lasted longer, it is entirely possible that New York City, as well as London, could have been on the receiving end of these Nazi V-2 missiles!

CAPT TRUAX/AEROJET SEA LAUNCHES

Although Wernher von Braun did not consider the floating launch of large liquid propellant boosters practical for NASA uses, another highly respected rocket engineer thought otherwise. Capt. Bob Truax, USN Retired, promoted the idea of floating launch using large pressure fed liquid rockets. Working for Aerojet General in Sacramento, California, CAPT Truax began working his way up the floating launch research ladder. His first phase involved static, and then partially restrained, underwater rocket firings. His first free flight vehicle was a converted AEROBEE 100 probe, which he renamed SEABEE. Lacking a range and facilities for launch, he contacted Project HYDRA at Point Mugu and an agreement for a joint operation was reached. The Aerojet team would handle all aspects of fueling, rocket preparation and firing. The Navy HYDRA team would provide the seaplane beaching gear for deployment in the ocean off Point Mugu, and other support such as radar and optical tracking, plus telemetry. A series of short-burn launches was planned for the SEABEE, to demonstrate parachute recovery and re-use of the same rocket. The first launch in 1961 was totally successful with the rocket recovered at sea after a normal parachute descent; but, on the second launch the parachute failed and the SEABEE was extensively damaged. A somewhat larger vehicle designed by CAPT Truax was named SEA-HORSE, but it was never launched. An even larger Truax design (think BIG!) was the SEA-DRAGON, a 20,000 ton monster designed to put a 1,000 ton payload into low earth orbit! [9]

RUSSIAN FLOATING-LAUNCH OPERATIONS

In 1975 the author, now retired from the Navy and working for a defense contractor, undertook a study of USSR submarine launched ballistic missiles (SLBM's). Particular attention was paid to their possible use of the floating launch technique. Early on, a reference was spotted in *Space and Missiles Magazine*, published in 1961 confirming Soviet use of the floating launch.[10] The Soviet Navy, probably building on the experience of their captive German missile scientists and engineers, had developed the Golem Missile It was a floating launched, relatively short range missile, equipped with an aft ballast tank for erection to the vertical. As the ballast tank was attached directly to the missile, it was apparent that this was not a cannister launch, but rather a true "HYDRA" launch. It was also reported in the magazine that a Soviet submarine could tow up to three of these missiles. After a detailed mathematical analysis of later SLBM launches, using data from a variety of sources, it became apparent to the author that the then current stable of Soviet naval missiles (the SSN-6 and SSN-8) had quite different launch signatures than the US POLARIS/POSEIDON missiles. For one thing, none of the Russian SLBM's exhibited the broaching (off-vertical water exit) so common to the US SLBM's! Another obvious data point was that the liquid-propellant Soviet missiles had an ideal sea-water specific gravity of slightly less than unity, clearly implying a floating launch. Additional proof consisted of comparisons between the Soviet SS-N-6 and the US HYDRA II boilerplate missile. By chance, these two vehicles had the same nearly the same length and the same thrust-to-weight ratio (1.8). It was not at all surprising that they displayed the same launch signatures (the duration of the in-water acoustic pulse and a distinctive acceleration profile that was dominated by bouyant effects). Apparently, the Soviet naval missile engineers had adopted the simpler and more stable floating launch technique for their SLBM's; although the missiles themselves were carried in vertical tubes within the submarine, they were released from the submarine at much lower velocity than their US counterparts, rising to the surface due to their inherent buoyancy. Only after they stabilized, floating vertically at the surface, and well behind the submarine, was the rocket firing initiated! Probably, less than a minute would elapse between release of the missile from the submarine and the rocket firing at the ocean surface. Interestingly, the Soviets had demonstrated an extremely rapid ripple fire capability with several missiles (easily accomplished when the missiles were floating in a line astern of the submarine). The US POLARIS/POSEIDON missiles used a much different technique; they were fueled by solid propellants and were thus much more dense than their Russian counterparts (sea water specific gravity greater than 1.0). They were literally blasted out of the submarine's tubes by a gas generator fueled by a solid propellant. The conclusion was inescapable- the submerged Soviet submarines released their missiles, which then rose to the surface. Then, floating vertically, ignition and lift-off occurred. The Russians were using the HYDRA floating launch technique to launch their newer liquid-propelled SLBMs capable of launch from submerged submarines! This would have been a logical step, since they had already been using a floating launch with the the towed Golem missile. The only difference was that these later operational SLBM missiles were carried in vertical tubes in the submarine rather than being towed, as was the case with Golem. In view of the 2-3 years span (minimum) it would have taken to develop Golem, it seems quite possible that the Soviet Navy was actually ahead of the US Navy in the invention, development and application of the vertical floating launch in 1960, when the US Navy's HYDRA program was begun! If so, it would not have been the first time in that an invention had been conceived independently and concurrently, in different countries

SEA-BASING THE MX MISSILE USING THE FLOATING LAUNCH

In the 1980-1981 time frame, the US Air Force was proposing a new generation ICBM called the MX missile. Their proposed basing schemes involved some complicated and very expensive approaches. One typical scheme was to have 200 missiles constantly on the move among 4600 different concrete shelters (a "random shell game"). The author, in a cover article for *National Review* magazine, compared the Air Force's estimates on the amount of concrete and steel required for this system with data furnished from the French military on the Maginot Line specifications.[11] The Air Force's MX system used six times the amount of concrete and steel as the Maginot Line, and covered twenty times the area. The author proposed, and completed, a funded study on sea-basing the MX, for the Office of Technology Assessment. It was evident that large cost savings could be realized by sea-basing MX on fast SL-7 containerships (that were capable of 34 knots).[12,13,14,15,16] Even more important, though, was the fact that counterstrikes against such a sea-based system would not incur the tens of millions of civilian casualties that would certainly result from basing MX's inside the US borders! Eventually, the Air Force placed these missiles in silos, by default.

STARSTRUCK, INC'S DOLPHIN ROCKET

In the early 1980's, a small enrepreneurial company, Arc Technologies, was formed to exploit the technology of hybrid rockets (solid fuel, with liquid oxidizers). The company was intent on developing low-cost satellite boosters for commercial purposes. Their strategy was to avoid the use of government funding (with all its associated beurocratic red-tape). Instead, they relied solely on private venture capital. A large number of static tests of the hybrid rockets were successfully conducted in the Mojave Desert in California. The author, as a consultant, succeeded in convincing the directors of this commercial venture that the use of a floating launch would eliminate the need for constructing costly concrete and steel launch facilities on land. Also, it would bypass a lot of safety problems and insurance costs associated with launching from a populated coastline. Accordingly, the company, now renamed as Starstruck Inc., proceeded to develop a single-stage prototype for a floating launch satellite booster. The first test vehicle, named DOLPHIN, was intended to approximate the first stage of a multi-stage satellite launch vehicle (SLV). This test rocket was carried on the after deck of a small oil-rig support vessel. At the launch site, the DOLPHIN was released to slide down an inclined stern ramp. Having a natural horizontal floating attitude, it was necessary to provide extra weight at the tail of the rocket to make it float vertically. The simple expedient of hanging a concrete block from the nozzle by a rope was adopted. This block was dropped off the ship a few seconds after the rocket. At rocket ignition, the rope burned through, and the concrete sunk to the bottom; DOLPHIN leaped from the water vertically, under the combined forces of rocket thrust plus water buoyancy. After three aborted attempts, DOLPHIN was finally successfully launched off San Clemente Island, California, in August 1984.

THE US NAVAL RESEARCH LABORATORY'S SEALAR PROGRAM

In 1987, the Naval Center for Space Technology at the Office of Naval Research, recognizing the advantages of sea launch coupled with the possibility of recovering and reusing the rocket hardware, initiated the Sea Launch and Recovery Program (SEALAR).[17] A contract was let to Truax Engineering Inc.- (CAPT Bob Truax, USN ret.). Approximately $15.2M was spent by the Navy through 1992 on this project. Drop tests of rocket hardware from helicopters resulted in some successes and some failures. Underwater static tests were conducted successfully, but no actual launches were ever completed. Lack of funding and lack of interest within the Navy (due largely to DoD policies assigning all space launch responsibilities to the USAF) doomed this effort from the outset.

THE FLOATING LAUNCH STARBIRD PROBE

In 1988, while the author was employed at Science and Technology Associates, Inc. (STA), a contract was obtained from the Strategic Defense Initiative Office (SDIO) which was headed at the time by GEN Abrahamson, USAF) for a feasibility study on using the floating launch for the STARBIRD target probe rocket. The mission of this probe was to carry targets for orbiting sensors. The probe was required to achieve an approximately parallel (but sub-orbital) trajectory about 200 km beneath the orbiting sensors. Other contractors concentrated on the more conventional launch method, employing a hard concrete stand based on Wake Island. Although the STA study conclusively demonstrated considerably decreased overall costs, and far greater flexibility as to launch sites and launch windows for sea-launching (due to the inherent mobility of the sea-launch), the US Army Ballistic Missile Office opted for the land-based method at Wake Island in the Pacific.

SURF: A JOINT US/RUSSIAN VENTURE TO CONVERT RUSSIAN SLBM'S INTO SATELLITE BOOSTERS

In January, 1993, an article appeared in the *Washington Times* newspaper by ADM Thomas H. Moorer, USN (ret), formerly Chief of Naval Operations and Chairman of the Joint Chiefs of Staff. [18] The article advanced the idea that naval strategic missile hardware (rocket motors, guidance, etc.), but *sans* warheads of course, could be inexpensively converted into commercial satellite boosters, using the HYDRA floating launch concept.

Shortly after ADM Moorer's article appeared, a mixed Russian delegation contacted the Admiral and his associates, expressing considerable interest in the concept. At the time, the Russian Navy was in dire straits, lacking funds to adequately pay and house their sailors. Their proposal was to jointly develop a floating launch satellite booster using excess Russian SLBM's with the warheads removed. Profits from the venture would be shared between the US investors and the Russian Navy- chiefly for providing badly needed housing in Russia. Very quickly there was a meeting of the minds, and a US/Russian joint venture was set up. On the US side, a US corporation named Sea Launch Investors (SLI), headed by Admiral Moorer, was set up. The author was designated Vice President for Engineering, to capitalize on his experience with sea-launch. Another ex-naval officer, CDR Tom Schaaf, USN (ret), handled much of the strategic and business planning. SLI also had legal and financial representatives on its board. Admiral Novoselov (Russian Navy ret.) was spokesman for and leader the Russian joint venture team. The Makeyev Design Bureau was to be the principal technical agency supporting the effort. They were the designers and developers of a long line of Soviet/Russian SLBM's. Several Russian bankers and entrepreneurs rounded out the Russian team. The Russian side agreed to provide the excess SLBM hardware, the launch support ship, and the rocket technicians. The US side would be responsible for gathering the necessary seed money, and for lining up potential customers among the US satellite industry. It was recognized that there would be many new launch requirements, given the number of new satellite communications systems that were in the planning stage (mainly in the US).

In order to alleviate concerns about commencing such a joint venture with a former enemy, Admiral Moorer and his SLI staff held meetings with all of the relevant branches of the US government. This included the State Department, the Commerce Department, the Security Council, US Senators and Representatives among others. None of these meetings revealed any grounds or issues that would invalidate our joint efforts with the Russians. Our trans-Atlantic communications with the Russians were quickly augmented and many more details were ironed out, by long distance telephone, fax, or e-mail.

Initial design studies by Makeyev engineers were centered around the use of the liquid-fueled SSN-23 "SHTIL) SLBM. The author advised the Makeyev designers that the limited capability of that rocket alone (approximately 150 kg to low earth orbit) was not sufficient to satisfy the majority of the new launch requirements. He suggested that they use strap-on solid rockets to increase the performance, assuming that the Russian approach would be to use several strap-on solid motors arrayed radially, similar to the US DELTA booster configuration. The Makeyev designers promised to come up with a design that would provide the additional performance needed.

In April, 1993, SLI representatives visited the Russian Federation. Headed by Admiral Moorer, The first stop was Moscow, where we called on the Chief of the Russian Navy in the Russian Naval Headquarters in downtown Moscow. The joint venture was discussed, and we were assured of the full support of the Russian Navy; that included a substantial number of SLBM missiles needed to establish a workable program. We also had meetings with Russian parliamentarians in key positions (corresponding to our congressional members of the Armed Services and Commerce Committees); these meetings also were strongly supportive of our efforts.

Admiral Novoselov, Russian Navy (retired), was to head up the Russian team; several other retired naval officers with submarine and missile experience were also on the team.

From Moscow, we flew a Russian executive jet to Chelyabinsk, a city in the Ural Mountains, accompanied by the Vice Chief of the Russian Navy. We proceeded by bus for 2 or 3 hours to the small town of Miass. On the outskirts of town was the formerly secret USSR development center code-named Chelyabinsk 65. It was here that the Makeyev Design Bureau was located. There, we held detailed technical and business sessions with our Russian counterparts. The author's major interest was in the technical area, and the Russian engineers' solution to the "strap-on" suggestion was intriguing. Instead of using several small solid rocket motors, they had joined a single first stage motor from their largest solid-fuel SLBM, the SSN-20, under the entire SSN-23. It was an extremely clean and efficient design, and it represented the ultimate in a floating launch vehicle. The Russians had named the new vehicle Priboy ("SURF" in English). The support vessel selected was the amphibious support ship Ivan Rogov, similar to the USS ALAMO and USS POINT DEFIANCE the author had used for HYDRA tests in the Pacific over thirty years previously. This ship was capable of transporting three SURF satellite boosters to any desired ocean launch site (including the equator). At the conclusion of the meetings at the Makeyev Design Bureau, Admiral Moorer and Mr. Velichko signed an agreement was mutually hammered out between the two groups.

In June of 1993, the Russians, headed by Admiral Noveselov, visited the US. By now, SLI had set up an office in Fairfax, Virginia. Further discussions between the Russian and US partners were held, and at this point an international corporation (registered in the Bahamas) was formed to represent both sides of the joint venture.

In the following months, SLI attempted to gain the support of the US government. An attempt was made to obtain funding under the Nunn-Lugar Act, under which the US provided funding to Russia in order to assist in carrying out the deactivation of strategic weapons. We pointed out that two Russian SLBMs would be effectively be destroyed for each satellite launch the joint venture completed. Unfortunately, support from this source was not forthcoming. Finally, the US/Russian joint venture lost momentum under mounting opposition from various quarters. The US Arms Control and Disarmament Agency appeared to be concerned about the extreme mobility of the system, and the possibility that our satellite boosters could be re-converted at sea back into missiles! In spite of our assurances that suitable controls could be implemented negating this possibility, they remained adamant. In spite of the excellent support we had received from the Russian Navy and Russian government, the political problems on the US side proved insurmountable.

We had also seen strong opposition on the part of the current Western launch providers (who certainly did not want this type of threatening competition entering their business, and who undoubtedly relayed their fears to US government officials). The author finally resigned from SLI in July 1995; the present status of the company is in limbo.

THE BOEING SEA-LAUNCH

Although not a true floating launch, the approach to flexible, low-cost launching being developed by the Boeing/Kvaerner/Yuzhnoye team is worthy of mention in this paper. Using a converted North Sea oil rig as a mobile launch platform and a custom designed support ship capable of transporting extra ZENIT boosters to the equator, the Boeing Sea Launch Limited Partnership is poised to compete head to head with the ARIANEs, the DELTAs and the ATLASes, for launching large geostationary communications satellites into orbit directly from the equator. Their success might in large measure, pave the way and provide added interest in developing the truly low-cost, mobile and flexible launch method represented by the floating launch.

THE FUTURE OF FLOATING SEA-LAUNCH

The author, in spite of numerous setbacks in his own attempts to launch satellites from the ocean, remains optimistic that someday a successful effort to orbit satellites using a floating launch will become a reality. He has watched, for decades, the expensive false starts by NASA and USAF to develop a true low cost satellite launch capability, under a variety of names and acronyms. Literally billions of dollars of taxpayers' money have been wasted, with little or nothing to show for the investment. Had even a fraction of this money been used to seriously develop the floating launch method, the cost of orbiting satellites could probably have been reduced by as much as 50%! Perhaps a new private venture can be mounted in the future that will succeed by capitalizing on the obvious advantages and flexibility of the "no-cost launch pad"! New technology is available now that greatly increases the attractiveness of the floating launch. We now have GPS guidance and control, an emerging hybrid rocket technology, lightweight and strong composite materials for rocket structures, improved rocket nozzles, miniaturized electronics, advanced technology power supplies including more efficient batteries, and advanced computers and microprocessors. The list goes on and on; it is the author's humble opinion that in today's world it is easier by far to design and build a floating launch satellite booster than it would have been two or three decades ago.

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